CLAIMS

We claim:

1. A method for processing seismic data to estimate time shift resulting from velocity anisotropy in the earth's subsurface, comprising:

forming a gather of seismic data traces; and

cross-correlating selected seismic data traces included in said gather within selected time windows to estimate the time shift in the seismic data traces included in said gather resulting from velocity anisotropy in the earth's subsurface.

2. The method of claim 1 further comprising adjusting seismic data traces included in said gather by the amount of the estimated time shift in said adjusted seismic data trace resulting from velocity anisotropy

3. The method of claim 2 further comprising performing an amplitude variation with incidence angle analysis on said adjusted seismic data traces.

4. The method of claim 2 further comprising performing an amplitude variation with azimuth analysis on said adjusted seismic data traces.

5. The method of claim 2 further comprising:

determining the incidence angle for seismic data traces included in said gather; and

applying a least squares analysis process to reflection coefficient, source-receiver azimuth angle and incidence angle data for seismic data traces included in said gather to calculate the amplitude variation with azimuth and amplitude variation with offset in seismic data traces included in said gather.

6. The method of claim 2 further comprising applying a least squares analysis process to the time shifts of said seismic data traces to calculate the velocity variation with azimuth in seismic data traces included in said gather.

7. A method for processing seismic data comprising:

forming a gather of seismic data traces;

performing a surface consistent statics computation on seismic data traces included in said gather;

cross-correlating successively selected seismic data traces in said gather to estimate the time shift in seismic data traces included in said gather resulting from azimuthal velocity anisotropy in the earth's subsurface, applying a least squares analysis process to the time shifts of said seismic data traces to calculate the velocity variation with azimuth in seismic data traces included in said gather;

utilizing the calculated velocity variations with azimuth to calculate time shifts in seismic data traces included in said gather;

applying said calculated time shifts to said seismic data traces included in said gather; and

applying a least squares analysis process to reflection coefficient, source-receiver azimuth angle and incidence angle data for seismic data traces included in said gather to calculate the amplitude variation with azimuth and amplitude variation with offset in seismic data traces included in said gather.

8. A method for processing seismic data to estimate time shift resulting from velocity anisotropy in the earth's subsurface, comprising:

forming a gather of seismic data traces;

forming a pilot trace by combining a selected plurality of said seismic data traces within a selected time window; and

cross-correlating a selected seismic data trace included in said gather with said pilot trace to estimate the time shift in said selected seismic data trace resulting from velocity anisotropy in the earth's subsurface.

9. A method for processing seismic data to estimate time shift resulting from velocity anisotropy in the earth's subsurface, comprising:

(a) forming a gather of seismic data traces;

(b) forming a pilot trace by combining a selected plurality of said seismic data traces within a selected time window;

(c) cross-correlating a selected seismic data trace included in said gather with said pilot trace to estimate the time shift in said selected seismic data trace resulting from velocity anisotropy in the earth's subsurface; and

repeating steps (b)and (c) until all seismic data traces within said gather have been cross-correlated with a pilot trace.

10. A method for processing seismic data, comprising:

(a) forming a gather of seismic data traces;

(b) forming a pilot trace by combining a selected plurality of said seismic data traces within a selected time window;

(c) cross-correlating a selected seismic data trace included in said gather with said pilot trace to estimate the time shift in said selected seismic data trace resulting from velocity anisotropy in the earth's subsurface;

repeating steps (b) and (c) until all seismic data traces within said gather have been cross-correlated with a pilot trace; and

adjusting each said selected seismic data trace by the amount of the estimated time shift in each said selected seismic data trace resulting from velocity anisotropy.

11. The method of claim 10 further comprising performing an amplitude variation with incidence angle analysis on said adjusted seismic data traces.

12. The method of claim 10 further comprising performing an amplitude variation with azimuth analysis on said adjusted seismic data traces.

13. A method for processing seismic data, comprising:

(a) forming a gather of seismic data traces;

(b) forming a pilot trace by combining a selected plurality of said seismic data traces within a selected time window;

(c) cross-correlating a selected seismic data trace included in said gather with said pilot trace to estimate the time shift in said selected seismic data trace resulting from velocity anisotropy in the earth's subsurface;

repeating steps (b) and (c) until all traces within said gather have been correlated with a pilot trace;

adjusting each said selected seismic data trace by the amount of the estimated time shift in each said selected seismic data trace resulting from velocity anisotropy;

determining the incidence angle for each selected seismic data trace; and

applying a least squares analysis process to reflection coefficient, source-receiver azimuth angle and incidence angle data of said seismic data traces to calculate the amplitude variation with azimuth and amplitude variation with offset in seismic data traces included in said gather.

14. A method for processing seismic data, comprising:

(a) forming a gather of seismic data traces;

(b) forming a pilot trace by combining a selected plurality of said seismic data traces within a selected time window;

(c) cross-correlating a selected seismic data trace included in said gather with said pilot trace to estimate the time shift in said selected seismic data trace resulting from velocity anisotropy in the earth's subsurface;

repeating steps (b) and (c) until all seismic data traces within said gather have been correlated with a pilot trace; and

applying a least squares analysis process to the time shifts of said seismic data traces to calculate the velocity variation with azimuth in seismic data traces included in said gather.

15. The method of claim 13 further comprising utilizing a least squares analysis to estimate errors associated with the calculation of amplitude variation in said selected seismic data traces.

16. The method of claim 14 further comprising utilizing a least squares analysis to estimate errors associated with the calculation of time shift variation in said selected seismic data traces.

17. The method of claim 14 further comprising utilizing a least squares analysis to estimate errors associated with the calculation of velocity variation in said selected seismic data traces.

18. A method for processing seismic data comprising:

(a) forming a gather of seismic data traces;

(b) performing a surface consistent statics computation on said seismic data traces;

(c) cross-correlating successively selected seismic data traces in said gather with a pilot trace formed by combining a selected plurality of seismic data traces in said gather within selected time windows to estimate the time shift in said seismic data traces resulting from azimuthal velocity anisotropy in the earth's subsurface, and applying a least squares analysis process to the time shifts of said seismic data traces to calculate the velocity variation with azimuth in seismic data traces included in said gather;

(d) utilizing the calculated velocity variations with azimuth to calculate time shifts in seismic data traces included in said gather;

(e) applying said calculated time shifts to said seismic data traces included in said gather;

repeating steps (b) - (e); and

applying a least squares analysis process to reflection coefficient, source-receiver azimuth angle and incidence angle data of said seismic data traces to calculate the amplitude variation with azimuth and amplitude variation with offset in seismic data traces included in said gather.

19. A method for processing seismic data, comprising:

(a) forming a gather of seismic data traces;

(b) selecting a time window of said gather;

(c) selecting a plurality of said traces;

(d) summing said plurality of traces within said time widow;

(e) selecting a trace from said gather and cross-correlating said selected trace with said summed plurality of traces;

(f) determining a time displacement of said selected trace which results in a substantially maximum correlation of said selected trace with said summed plurality of traces within said selected time window;

(g) repeating steps (c) - (f) for successive traces and selected summed pluralities of traces until a time displacement has been determined for each trace within said gather which results in a substantially maximum correlation of each trace of said gather with a summed plurality of traces within said time window; and

(h) repeating steps (b) - (g) for successive time windows within said gather.

20. A method for processing seismic data to compensate for time shifts in said data resulting from azimuthal anisotropy, comprising:

(a) forming a gather of seismic data traces;

(b) selecting a time window of said gather;

(c) selecting a plurality of said traces;

(d) summing said plurality of traces within said time widow;

(e) selecting a trace from said gather and cross-correlating said selected trace with said summed plurality of traces;

(f) determining a time displacement of said selected trace which results in a substantially maximum correlation of said selected trace with said summed plurality of traces within said selected time window;

(g) repeating steps (c) - (f) for successive traces and selected summed pluralities of traces until a time displacement has been determined for each trace within said gather which results in a substantially maximum correlation of each trace of said gather with a summed plurality of traces within said time window;

(h) repeating steps (b) - (g) for successive selected time windows of said gather;

(i) applying the determined time displacement for each trace within each said window to the trace at the center point of each said time window; and

(j) interpolating time shifts for the remaining portion of each data trace between the window center points.

21. The method of claim 20 further comprising:

determining the reflection coefficient and azimuthal angle for each trace of the gather;

calculating the value of the incidence angle for each trace of the gather; and

utilizing a least squares method to compute reflection coefficients as a function of azimuthal angle and incident angle for the seismic traces of the gather.

22. The method of claim 20 further comprising utilizing a linear least squares method to calculate the semi-major and semi-minor axis, and the angle between a predefined zero azimuth direction and the semi-major axis direction of the an ellipse representing the azimuthal variation in velocity.

23. The method of claim 22 further comprising:

formulating a matrix for a least squares analysis for estimating the errors associated with the calculation of the time shift variation with azimuth;

computing an error estimate by taking the square root of the diagonals of said matrix; and

comparing the estimated error to the computation of the azimuthal velocity variation to confirm whether or not the azimuthal velocity variation has an acquisition footprint.

24. A digital computer programmed to utilize seismic data traces obtained over a region of the earth's subsurface to perform a process comprising the steps of:

forming a gather of seismic data traces;

forming a pilot trace by combining a selected plurality of said seismic data traces within a selected time window; and

cross-correlating a selected seismic data trace included in said gather with said pilot trace to estimate the time shift in said selected seismic data trace resulting from velocity anisotropy in the earth's subsurface.

25. A device which is readable by a digital computer having instructions defining the following process and instructions to the computer to perform said process:

forming a gather of seismic data traces;

forming a pilot trace by combining a selected plurality of said seismic data traces within a selected time window; and

cross-correlating a selected seismic data trace included in said gather with said pilot trace to estimate the time shift in said selected seismic data trace resulting from velocity anisotropy in the earth's subsurface.

26. The device of claim 25 wherein said device is selected from the group consisting of a magnetic tape a magnetic disk, an optical disk and a CD-ROM.